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Renewable energy sources in Turkey for climate change mitigation and energy sustainability

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ABSTRACT

In Turkey, there is a much more potential for renewables, but represent about 37% of total energy production and 10% of total energy consumption. This share is not enough for the country and the governments should be increase to this situation. Renewable energy technologies of wind, biomass, hydropower, geothermal, solar thermal and photovoltaics are finally showing maturity and the ultimate promise of cost competitiveness. With respect to global environmental issues, Turkey's carbon dioxide emissions have grown along with its energy consumption. States have played a leading role in protecting the environment by reducing emissions of greenhouse gases. In this regard, renewable energy resources appear to be the one of the most efficient and effective solutions for clean and sustainable energy development in Turkey. Turkey's geographical location has several advantages for extensive use of most of these renewable energy sources. Certain policy interventions could have a dramatic impact on shaping the relationship between geological, geographic and climatic conditions and energy production. This study shows that there is enough renewable energy potential in Turkey for fuels and electricity. Especially hydropower and biomass are very well.

Contents

1. Introduction

Energy is essential to economic and social development and improved quality of life in all countries [1]. Much of the world's energy, however, is currently produced and consumed in ways that could not be sustained if technology were to remain constant and if overall quantities were to decrease substantially [2]. Renewable energy supply in Turkey is dominated by hydropower and biomass, but environmental and scarcity-of-supply concerns have led to a decline in biomass use, mainly for residential heating [3].

The impacts of GHG emissions and the resulting climate change have a serious impact on the global economy, so the need to control atmospheric emissions of greenhouse and other gases

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and substances will increasingly need to be based on efficiency in energy production, transmission, distribution and consumption in the country [4]. Electricity supply infrastructures in many developing countries are being rapidly expanded as policymakers and investors around the world increasingly recognize electricity's pivotal role in improving living standards and sustaining economic growth [5]. Special interest in the electricity sector is due to its major role in emissions, its potential for emission reductions, and also as a supplier of a non-traded or semi-traded input and consumption good [6].

Climate change is a serious global concern, calling for changes in consumer behavior, but offering potential win–win opportunities. These include increased transfer of efficient technologies from industrialized to developing countries and incentives to investment through emerging voluntary and regulated emissions trading. According to the most recent climate projections, global climate change is expected to have considerable impacts on natural and human systems [7].

Turkey's population is growing and if Turkey uses only traditional energy sources, it simply will not have enough energy capacity for its population. The contribution to Turkey's sustainable and independent energy future of renewable energy sources has too large potential. These resources can help to reach the environmental goals of Turkey and to increase the security of energy supply by reducing the dependence on imported-fuel supplies. Renewable energy is the key to solving Turkey's energy-related challenges.

There is a growing concern that sustainable development may be compromised unless measures are taken to achieve balance between economic and environmental outcomes. Since the early 1980s, Turkish energy policy has concentrated on market liberalization in an effort to stimulate investment in response to increasing internal energy demand. The governments have continued this policy despite lower energy demand induced by the 2001 economic crisis. The need to control atmospheric emissions of greenhouse and other gases will increasingly need to be based on efficiency in energy production, and consumption in Turkey. This paper provides an overview of the renewable energy utilization for climate change mitigation and energy sustainability in Turkey.

2. Global energy consumption

Global energy consumption in the last half century has rapidly increased and is expected to continue to grow over the next five decades. The past increase was stimulated by relatively "cheap" fossil fuels and increased rates of industrialization in North America, Europe and Japan; yet while energy consumption in these countries continues to increase, additional factors make the picture for the future more complex [5]. On the positive side, the renewable energy technologies of wind, biofuels, solar thermal and photovoltaics are finally showing maturity and the ultimate promise of cost competitiveness [8–10].

The total primary energy demand in the world increased from 7223 Million tons of oil equivalent (Mtoe) in 1980 to 12,354 Mtoe in 2008 (Table 1), representing an average annual increase of 2% [5]. However, it is important to note that the average worldwide growth from 2000 to 2008 was 4.2% with the increase from 2004 to 2008 being 4.3%. The rate of growth is rising mainly due to the very rapid growth in Pacific Asia that recorded an average increase from 2001 to 2008 of 8.7% [5,6].

All renewables combined accounted for only 18% share of electricity production in the world, with hydroelectric power providing almost 90% of it [5,10]. Therefore, substituting fossil fuels with renewables for electricity generation must be an important part of any strategy of reducing CO_2 emissions into the atmosphere and combating global climate change [5]. Fig. 1 shows the greenhouse gas emissions.

Table 1
World primary energy demand by fuel (Mtoe).
Source: Ref. [5].

	2008	2015	2030
Coal	3284	4023	4908
Oil	4193	4525	5109
Gas	2612	2903	3670
Nuclear	720	817	901
Hydropower	275	321	414
Biomass and waste	1176	1375	1662
Other renewables	94	158	350
Total	12,354	14,121	17,014

Mtoe: Million tons of oil equivalent.

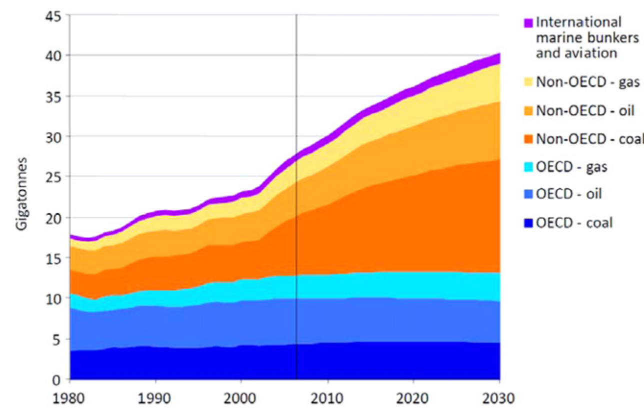


Fig. 1. World-wide greenhouse gas emissions (in Gton CO_2-equivalent) resulting from the useof fossil energy [5].

Table 2
Global renewable energy capacities in 2010.
Source: Ref. [10].

Renewable energy	Capacity
Power generation (GW)	
Wind power	198
Biomass power	62
Solar PV	40
Geothermal power	11
Concentrating solar power (CSP)	1.1
Hydropower	1010
Ocean power	0.3
Hot water/heating (GWth)	
Modern biomass heating	280
Solar colectors for hot water/space heating	185
Geothermal heating	52
Transport fuels (billion liters/year)	
Ethanol production	86
Biodiesel production	19

Renewable energy continued its strong growth in 2010 as well. In 2009, renewable energy supplied an estimated 16% of global final energy consumption including traditional biomass, hydropower, wind, solar, geothermal, modern biomass, and biofuels. Traditional biomass used primarily for cooking and heating in rural areas of developing countries, accounted for approximately 10% of the total renewable energy share [8–10]. In several countries, however, the growth in these renewable technologies far exceeds the global average. Table 2 shows the global renewable energy capacities in 2010.

New wind power capacity added during 2010 reached 39 GW, more than any other renewable technology and over three times the 11.5 GW of wind added worldwide just five years earlier [9]. As a result, existing capacity increased more than 24% relative to 2009, with total global capacity nearing 198 GW by year's end [9,10].

Solar photovoltaic (PV) capacity was added in more than 100 countries during 2010, ensuring that PV remained the world's fastest growing power-generation technology [9]. An estimated 17 GW of PV capacity was added worldwide in 2010, bringing the global total to about 40 GW—more than seven times the capacity in operation five years earlier. Total existing capacity of all PV grew 72% relative to 2009, with the average annual growth rate over the 2005 to 2010 period exceeding 49% [5,9,10].

By the end of 2010, total global geothermal installations came to just over 11 GW, up an estimated 240 MW from 2009, and geothermal plants generated about 67.2 TW h of electricity during the year [9]. The lack of available drilling rigs has hindered geothermal developers worldwide, while the lack of a qualified workforce has presented challenges in Kenya and elsewhere; it has been projected that by 2013, the need for drilling rigs in the United States alone will rise almost 150% [9,10].

Global hydropower production increased more than 5% in 2010, due greatly to new capacity and wet weather in China, and represented about 16% of global electricity production [9]. An estimated 30 GW of capacity was added during 2010, with existing global capacity reaching an estimated 1010 GW. The top countries for hydro capacity are China, Brazil, the United States, Canada, and Russia, which account for 52% of total installed capacity. Development in the USA has slowed recently due to the economic recession, but just over 0.02 GW of new hydro began operating in 2010 for a total of 78 GW. Russia has an estimated 55 GW [5,9,10].

3. Renewable energy and climate change

For development to be sustainable, delivery of energy services needs to be secure and have low environmental impacts [2]. Sustainable social and economic development requires assured and affordable access to the energy resources necessary to provide essential and sustainable energy services. This may mean the application of different strategies at different stages of economic development. To be environmentally benign, energy services must be provided with low environmental impacts, including GHG emissions [1,2].

The combustion of fossil fuels accounted for 56.6% of all anthropogenic GHG emissions (CO_2-Eq) in 2004 [5]. However, renewable energy technologies, which release much lower amounts of CO_2 than fossil fuels are growing [10–12].

Deployment of renewable energy has been increasing rapidly in recent years [8–10]. Under most conditions, increasing the share of RE in the energy mix will require policies to stimulate changes in the energy system. Government policy, the declining cost of many RE technologies, changes in the prices of fossil fuels and other factors have supported the continuing increase in the use of renewables. While renewable energy is still relatively small, its growth has accelerated in recent years, as shown in Fig. 2 [5,10]. In 2009, despite global financial challenges, renewables capacity continued to grow rapidly, including wind power (32%, 38 GW added), hydropower (3%, 31 GW added), grid connected photovoltaics (53%, 7.5 GW added), geothermal power (4%, 0.4 GW), and solar hot water/heating (21%, 31 GWth) [9]. Approximate 300 GW of new electricity generating capacity added globally over the two-year period from 2008 to 2009, 140 GW came from renewable energy additions.

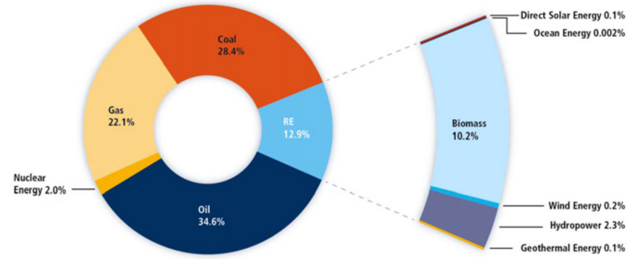


Fig. 2. Shares of energy sources in total global primary energy supply in 2008 [5,10].

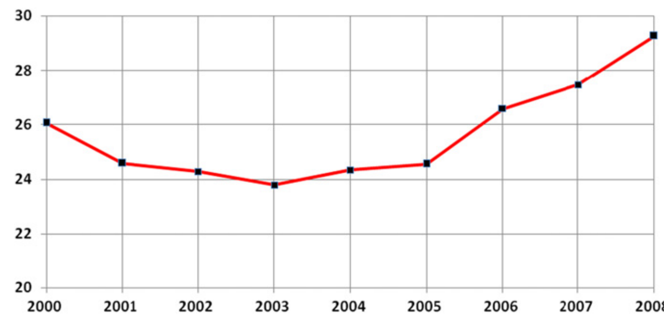


Fig. 3. Primary energy production in Turkey (Mtoe) [14].

Most renewable energy technologies have low specific emissions of CO_2 into the atmosphere relative to fossil fuels, which makes them useful tools for addressing climate change [10]. For a renewable resource to be sustainable, it must be inexhaustible and not damage the delivery of environmental goods and services including the climate system. To be sustainable, energy must also be economically affordable over the long term; it must meet societal needs and be compatible with social norms now and in the future. It is important to assess the entire lifecycle of each energy source to ensure that all of the dimensions of sustainability are met [9,10].

4. Energy consumption in Turkey

In general, the net energy consumption in Turkey is met by imports, and the share of imports continues to increase each year. Turkey is a natural bridge between the energy-rich Middle East and Central Asian regions. Turkey's geographical location has several advantages for extensive use of most of these renewable energy sources. Renewables appear to be the one of the most effective solutions for clean and sustainable energy development in Turkey.

Turkey is an energy importing country; more than half of the energy requirement has been supplied by imports [11,12]. Oil, coal and gas have the biggest share in total primary energy consumption [13–15]. Turkey, with its young population and growing energy demand per person, its fast growing urbanization, and its economic development, has been one of the fast growing power markets of the world for the last two decades. It is expected that the demand for electric energy in Turkey will be 573 billion kW h by the year 2020 and 760 billion kW h by the year 2030 [13–16]. Turkey's electric energy demand is growing about 4%–6% yearly due to fast economic growing [13–17].

In 2008, primary energy production (see Fig. 3) and consumption has reached 27.45 and 107.62 million tons of oil equivalent (Mtoe) as shown in Tables 3 and 4 [14]. The most significant developments in production are observed in hydropower, geothermal, solar energy production. Turkey's use of hydropower,

Table 3
Total energy production in Turkey (Mtoe).
Source: Ref. [14].

Energy sources	2008	2010	2020	2030
Coal and lignite	15.40	26.15	32.36	35.13
Oil	2.24	1.13	0.49	0.17
Gas	0.94	0.17	0.14	0.10
Nuclear	-	-	7.30	14.60
Hydropower	3.66	5.34	10.00	10.00
Geothermal	0.74	0.98	1.71	3.64
Wood and biomass	5.10	5.12	4.96	4.64
Solar/wind/other	0.78	1.05	2.27	4.28
Total production	28.86	39.94	59.23	72.56

Table 4
Total energy consumption in Turkey (Mtoe).
Source: Ref. [14].

Energy sources	2008	2010	2020	2030
Coal and lignite	30.21	39.70	107.57	198.34
Oil	33.16	51.17	71.89	102.38
Gas	33.65	49.58	74.51	126.25
Nuclear	-	-	7.30	14.60
Hydropower	3.66	5.34	10.00	10.00
Geothermal	0.74	0.97	1.71	3.64
Wood and biomass	5.10	5.12	4.96	4.64
Solar/wind/other	0.78	1.05	2.27	4.28
Total consumption	107.30	152.93	280.21	464.13

Table 5
Renewable energy resources in Turkey (1000 toe/yr).
Source: Ref. [14].

	2000	2003	2005	2007
Total energy demand	77624	79402	85340	101510
Total energy production	26808	23873	23626	27279
Supply by renewables	**10149**	**10036**	**10131**	**9604**
Biomass and waste	6546	5783	5332	5023
Wood/wood waste	6541	5775	5325	4994
Biogas	5	8	7	15
Municipal solid waste	-	-	-	-
Biofuels	0	0	0	14
Wind energy	3	5	5	31
Solar energy	262	350	385	420
Hydropower	2655	3038	3402	3083
Geothermal energy	684	860	1007	1048
Share (%)	**13.07**	**12.64**	**11.87**	**9.46**
Biomass and waste	8.43	7.28	6.25	4.95
Wood/wood waste	8.43	7.27	6.24	4.92
Biogas	0.01	0.01	0.01	0.01
Municipal solid waste	-	-	-	-
Biofuels	0.00	0.00	0.00	0.01
Wind energy	0.00	0.01	0.01	0.03
Solar energy	0.34	0.44	0.45	0.41
Hydropower	3.42	3.83	3.99	3.04
Geothermal energy	0.00	1.08	1.18	1.03

geothermal and solar thermal energy has increased since 1990 [13]. However, the total share of renewable energy sources in total final energy consumption (TFEC) has declined, owing to the declining use of non-commercial biomass and the growing role of natural gas in the system. Turkey has recently announced that it will reopen its nuclear program in order to respond to the growing electricity demand while avoiding increasing dependence on energy imports [11–15].

Along with the economic growth and population increase, significant increases were observed both in primary energy and in electricity consumption during the 9th Plan period [16]. Consumption of primary energy reached 105.61 Mtoe as of the end of 2008 with an annual average increase of 3.0% while electricity consumption reached 199.4 billion kW h with an annual average increase of 4.8% during this period. These increases are more evident in the period following 2003, since the impact of the 2001 economic crisis was alleviated, and the economy stabilized. During this term, primary energy and electricity utilization grew at an annual average rate of 5.8% and 6.8%, respectively [13,14].

5. Renewable energy in Turkey

Renewable energy supply in Turkey is dominated by hydropower and biomass (Table 5), but environmental and scarcity-of-supply concerns have led to a decline in biomass use, mainly for residential heating [17–20]. Total renewable energy supply declined from 1990 to 2008, due to a decrease in biomass supply [12,18]. As a result, the composition of renewable energy supply has changed and wind power is beginning to claim market share [13]. The share of biomass in the renewable energy share is expected to decrease with the expansion of other renewable energy sources as a contributor of air pollution and deforestation. Table 5 shows renewable energy resources in Turkey [13–15]. Table 6 also shows the potentials for investment of the renewable energies in Turkey.

Total gross hydropower potential and total energy production capacity of Turkey are nearly 50 GW and 112 TW h/yr, respectively and about 30% of the total gross potential may be economically exploitable [21–23]. At present, only about 35% of the total hydroelectric power potential is in operation [21]. The national development plan aims to harvest all of the hydroelectric potential by 2020 [16]. The contribution of small hydroelectric plants to total electricity generation is estimated to be 5%–10% [23–26]. On the other hand, the Southeastern Anatolia Project (GAP) is one of the largest power generating, irrigation, and development projects of its kind in the world, covering 3.0 million ha of agricultural land [27]. This is over 10% of the cultivable land in Turkey; the land to be irrigated is more than half of the presently irrigated are in Turkey. The GAP project on the Euphrates and Tıgris Rivers encompasses 22 dams and 19 hydroelectric power plants. Once completed, 27 billion kW h of electricity will be generated and irrigating 1.7 million hectares [27].

Table 6
Potentials for investment for renewable energies in Turkey.
Source: Ref. [14].

Sectors	Million €	Remarks
Hydroelectric	114	Economical development potential of 28,600 MW, Corresponding 100,000 GW h/a
Wind power	57	Economical development potential of 48,000 MW With wind speed > 7 m/s
Solar thermal	165	Economical development potential of 131,000 GW h/a, Corresponding to approx. 300 million m^2 collector area
Biogas	4	Agricultural residual material and dung, when used for electricity generation, 1000 MWe and 7000 GW h/a
Total	340	

Among the renewable energy sources, biomass is important because its share of total energy consumption is still high in Turkey [28–31]. Since 1990, the contribution of the biomass resources in the total energy consumption dropped from 15% to 5% in 2008 [13–15].

Biomass in the forms of fuelwood and animal wastes is the main fuel for heating and cooking in many urban and rural areas [28]. The total recoverable bioenergy potential is estimated to be about 36 Mtoe in 2008 [28]. On the other hand, using vegetable oils as fuel alternatives has economic, environmental, and energy benefits for Turkey [30]. Animal wastes are mixed with straw to increase the calorific value, and are then dried for use [29–32].

Turkey is one of the countries with significant potential in geothermal energy and there may exist about 2000 MW_e of geothermal energy usable for electrical power generation in high enthalpy zones. Turkey's total geothermal heating capacity is about 31.500 MWth. At present, heating capacity in the country runs at 1220 MWth equivalent to 150,000 households. These numbers can be heightened some seven-fold to 6.880 MWth equal to 600,000 households through a proven and exhaustible potential in 2012. Turkey must target 1.2 million house holds equivalent 7.700 MWth in 2020 [33–37]. Fig. 4 shows the development of geothermal energy installed capacity in Turkey.

Turkey receives a high level of solar radiation throughout the year with mean daily sunshine duration of about 7.2 h and solar energy intensity of 12.96 MJ/m^2/d. The highest and lowest solar energy potential of Turkey is in the Southeast Anatolian region with an average solar radiation of 14.37 MJ/m^2/d and sunshine duration of 8.2 h/d and in the Black Sea region with an average solar radiation of 11.02 MJ/m^2/d and sunshine duration of 5.4 h per day, respectively [23]. The solar potential unconstrained by technical, economic or environmental requirements of Turkey is estimated at 90 Mtoe per year [13,38,39].

Total solar energy production of 0.290 Mtoe in 2001 increased to 0.420 Mtoe in 2008 and is projected to rise to 0.862 Mtoe by 2020 [23,38]. Flat plate solar collectors are the most widespread solar thermal application in Turkey, which are generally used for the production of commercial and domestic hot water, especially throughout the coastal regions. In 2008, Turkey had 12 million m^2 of collector surface area installed with a heat output of 0.4 Mtoe contributing to energy production [23].

In Turkey, electricity is mainly produced by thermal power plants, by consuming coal, lignite, natural gas, fuel-oil and geothermal energy, hydropower plants, and most recently wind energy [13–15]. The electricity requirement was reported as 194,000 GW h in 2008 [15]. The electricity is mainly produced by thermal power plants and accounted for 74.82% of the total, while hydro power energy was 25.11% and the wind power energy was 0.07%. In the thermal electricity production, the lignite part was 18.37% and natural gas was 44%. Compared to other energy sources, PV systems do not have sufficient contributions to gross electricity demand. There are no sufficient governmental driving forces to support PV systems in Turkey yet. Turkey's annual solar energy potential is estimated to be 1015 kW h, which is more than 5700 times of the present electricity consumption [23,38,39].

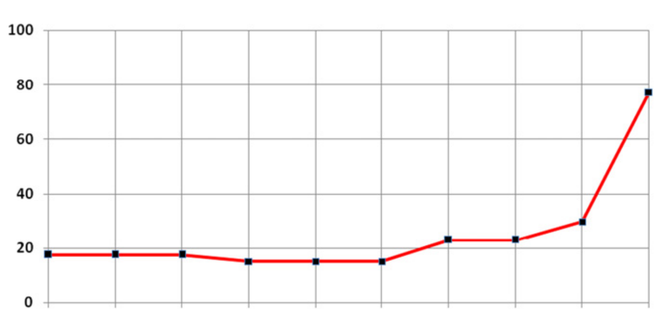


Fig. 4. Development of geothermal energy installed capacity (MW) [14].

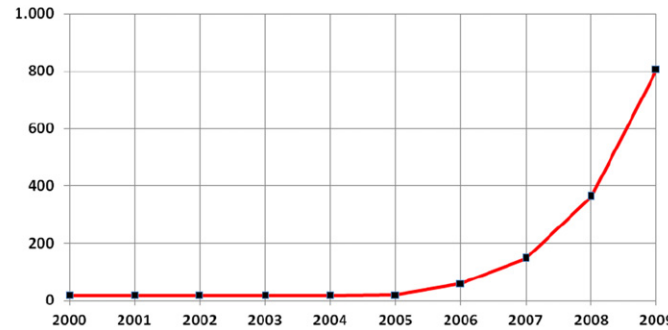


Fig. 5. Development of wind energy installed capacity (MW) [14].

There are a number of cities in Turkey with relatively high wind speeds. These have been classified into six wind regions, with a low of about 3.5 m/s and a high of 5 m/s at 10 m altitude, corresponding to a theoretical power production between 1000–3000 kW h/(m^2 yr). The most attractive sites are the Marmara Sea region, Mediterranean Coast, Agean Sea Coast, and the Anatolia inland. Capacity is likely to grow rapidly, as plans have been submitted for just under a further 600 MW of independent facilities. At start 2010, total installed wind energy capacity of Turkey is only 900 MW [40–47]. Fig. 5 shows the development of wind energy installed capacity in Turkey.

6. Climate change mitigation in Turkey

Turkey is a rapidly growing country whose income level is moving towards that of the rest of the OECD area [48]. This catch-up process has been associated with a rapid growth of greenhouse gas emissions. Nonetheless, carbon emissions from any country contribute equally to the pressure on the global climate [12]. Consequently, the major issue facing policy makers is how to contribute to reducing the burden on global resources at a low cost and without jeopardizing the rapid growth of the economy [48–50]. The use of renewable energy sources is becoming increasingly necessary, if we are to achieve the changes required to address the impacts of global warming [51].

Economy-wide greenhouse gas emissions from fuel combustion jumped 65% in the 1990s, in contrast to the more modest growth in the rest of the OECD area. The Turkish government is now in the process of developing a strategy to reduce the growth of greenhouse gases [12]. Turkey will have the obligation to implement measures and polices to mitigate greenhouse gas emissions but will not be required to meet a specific greenhouse gas emission target [48,49]. On the other hand, the privatization of the electricity companies will also result in new pricing policies. At present, demand for electricity is boosted by a high level of what is called "non-technical" system losses. In practice, this phrase refers both to electricity that is consumed through illegal connections to the network and non-payment of bills. The new distribution companies will need to invest in new metering systems to ensure that these practices end [12–15]. The problem may be difficult to settle, in that the new distribution companies have different profiles of losses, with illegal consumption rising to 50% in some areas. Enforcing normal contract discipline, though, would further add to the de-coupling of carbon emissions form GDP growth [13,47,48].

6.1. Emissions

Turkey has achieved decoupling of SO_x, NO_x and CO emissions from economic growth. Owing mainly to the rapid growth of primary energy consumption and the increasing use of domestic lignite, SO_2 emissions, in particular, have increased rapidly in recent years in Turkey. The major source of SO_2 emissions is the power sector, contributing more than 50% of the total emissions [52,53]. In 2008, estimated SO_2 emissions are 2.1 million tons, increased by 7% between 1990 and 2008, while GDP and fuel consumption increased by 32 and 28%, respectively. SO_x emission intensity (per unit of GDP) fell by 14% between 1990 and 2008. However, SO_x emission intensity is still over three times higher than the OECD average. Major contributors to SO_x emissions continue to be power plants (64.3%) and industrial combustion (25.6%) [12–15].

NO_x emissions, estimated at 1.1 million tons in 2008 [50]. NO_x emission intensity (per unit of GDP) decreased between 1998 and 2005 from 2.1 to 1.9 kg/USD 1000. However, NO_x emission intensity still exceeded the OECD average by more than 50%. The major contributor to NO_x emissions continued to be mobile sources. Their share in total emissions increased by 5% compared with 1998. Power stations and industrial combustion accounted for 16.9 and 18.8%, respectively [13,49,50].

Carbon monoxide emissions amounted to 3.2 million tons in 2008, a 30% decrease since 1990 and mostly come from non-industrial (39%) and mobile (38%) sources [47]. Since 1998, the contribution from non-industrial fixed sources has increased while that from mobile sources has decreased by 12% [13,49]. On the other hand, volatile organic compound (VOC) emissions have increased slightly. Total emissions were estimated at 562 million tons in 2008, with nonindustrial fixed sources contributing 32%, mobile sources 23% and solvents 29% of total VOC emissions [13,49,50].

Between 1990 and 2008 total greenhouse gas (GHG) emissions increased by 85% from 170 Tg/CO_2-eq in 1990 to 327.5 Tg/CO_2-eq in 2008 (Table 7) [49]. The energy sector accounted for 79% of the total in 2008. The other contributing sectors are the waste sector (9.3%), industrial processes (8.1%) and agriculture (5.1%). Most (92%) of total CO_2 emissions are from fossil fuel combustion [12,13,15,49]. Fig. 6 shows the CO_2 emissions from electricity generation power plants in Turkey.

6.2. Reducing pollution from energy production

The government further reformed the regulatory framework to reduce pollution from energy production. In 2006, the new Regulation on Control of Air Pollution from Industrial Plants set standards for emissions of NO_x, SO_2, CO and PM from combustion plants. PM and CO standards were lowered for both solid and liquid fuel-fired power plants. PM standards were tightened from 150 to 100 mg/m^3 for solid fuel-fired power plants and CO standards were lowered from 250 to 200 mg/m^3 (for solid fuel-fired plants) and from 175 to 150 mg/m^3 (for liquid fuel–fired plants) [12,13,15,49].

Table 7
Greenhouse gas emissions by gas (million tons CO_2-eq).
Source: Ref. [49].

Years	CO_2	CH_4	N_2O	Total
1990	139.6	29.2	1.3	170.1
1992	152.9	36.7	4.0	193.6
1994	159.1	39.2	2.2	200.5
1996	190.7	45.0	6.1	242.1
1998	202.7	47.7	5.6	256.6
2000	223.8	49.3	5.8	280.0
2002	216.4	46.9	5.4	270.6
2004	241.9	46.3	5.5	296.6
2006	266.3	51.4	3.6	323.4
2008	271.4	51.8	4.2	327.4

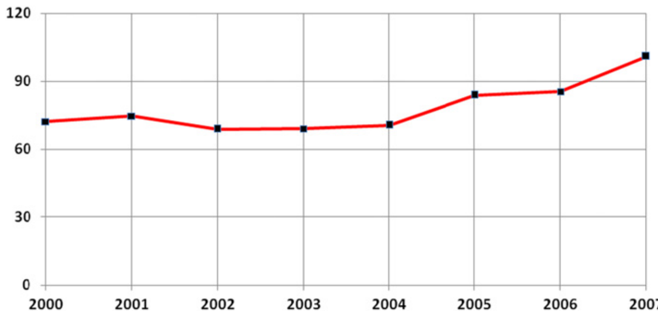


Fig. 6. The CO_2 emission from electricity energy production in Turkey (Million tons) [14,15].

Some investments have already been made, especially to address the environmental impacts of the high sulphur content of domestic lignite [12,19]. New lignitefired power plants have been equipped with flue gas desulphurization (FGD) technology to comply with regulations. Six of eleven pre-1986 lignite-fired plants have been retrofitted with electrostatic precipitators (ESP) to reduce particulate emissions. However, not all electrostatic precipitators are working at maximum efficiency [30,34]. Construction of one power plant based on circulating fluidised bed technology has recently been completed [48,49].

6.3. Improving energy efficiency

Energy intensity decreased by 8% between 1990 and 2005 and this value is below the OECD average. Its improvement through improved sectoral energy efficiencies is an important objective of Turkey, which should bring multiple benefits: economic benefits, environmental benefits and related health benefits [12,19]. Official studies have demonstrated that Turkey has large energy conservation potential (25%–30%). Energy efficiency policies have been implemented in the industrial, residential and services sectors. General investment support programs also have an indirect positive impact on energy efficiency [13]. There are no direct tax incentives to encourage end-use energy efficiency, nor is there any other kind of direct financial incentives. On the other hand, the National Energy Conservation Centre (EIE/NECC) has provided training to consumers on energy conservation measures, conducted energy audits in industry, maintained energy consumption statistics for the industrial sector and public buildings, and co-ordinated dialog and co-operation with the relevant institutions [13–15]. In 2004, the Energy Efficiency Strategy was adopted to support, in a more comprehensive way, energy efficiency in the final energy consumption sectors and more actively engage ministries and stakeholders in applying energy efficiency measures [23].

6.4. Promoting renewable energy

More than half of the renewables used in Turkey are combustible fuels and waste, the rest being mainly hydro, solar and geothermal. Turkey is richly endowed with hydropower, wind and geothermal resources. Sectoral studies have indicated that small-scale hydropower is under developed, and a total potential production of 33 TW h of electricity per year [21]. It is estimated that Turkey has the potential for up to 48,000 MW of wind power capacity, capable of generating about 25 TW h of electricity per year [13–15].

There is also large potential for geothermal and solar thermal applications in Turkey. Solar collectors are already a significant, market-driven business. The government expects the use of geothermal and solar energy to double between 2008 and 2020. On the other hand, commercial use of renewable energy has not developed rapidly. Financial assistance is being provided for the development of renewable energy projects. In 2008, USD 500 million was made available; by 2011, about half had already been committed to finance 36 projects with several other projects under preparation [13–15].

7. Conclusions

Climate change is one of the most difficult challenges facing the world today. Therefore, renewable energy resources will play an important role in the world's future. Optimal use of these resources minimizes environmental impacts. Renewables provide an excellent opportunity for mitigation of greenhouse gas. The potential of greenhouse gas mitigation depends on the use and availability of renewable energy sources and fuel replaced by it.

Air pollution is a significant environmental concern in Turkey. Therefore, renewable energy sources are becoming attractive solution for clean and sustainable energy future of Turkey. The resource availability is very important for the nature of the energy supply. Resource availability refers to the geological, geographic and climatic conditions. Turkey's geographical location has several advantages for extensive use of hydropower and biomass as renewable energy sources. Environmental and scarcity-of-supply concerns have led to a decline in biomass use, mainly for residential heating.

In recently, electricity has demand increased significantly; it is the fastest growing end-use of energy. Therefore, technical, economic and environmental benefits of hydroelectric power make it an important contributor to the future world energy mix. In the world, particularly in the developing countries renewable energy resources appear to be one of the most efficient and effective solutions for sustainable energy development. The role of hydropower in electricity generation is substantially greater than any other renewable energy technology in Turkey.

Turkey uses the energy sources inefficiently and consumes more energy to produce a product. Therefore, the production costs in this country are higher than the world's average. Energy policies of Turkish government should support the domestic renewable energy sources and use the installed power plants efficiently in Turkey.

Energy production from renewables should be improved in Turkey to reduce the dependency and environmental pollution and increase the development level of the country by increasing the economic level of the country. Positive achievements have been obtained in renewable energy development and manufacturing in Turkey over the past decade. Despite this, the authors believe that Turkey does not use its renewable energy sources efficiently and should promote new technologies and use all its renewable energy potential. On the other hand, the phenomenon of global climate change is a very serious economic, social and environmental problem. In order to diminish of this problem, the governments should be supported to utilizing renewables most effectively.

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